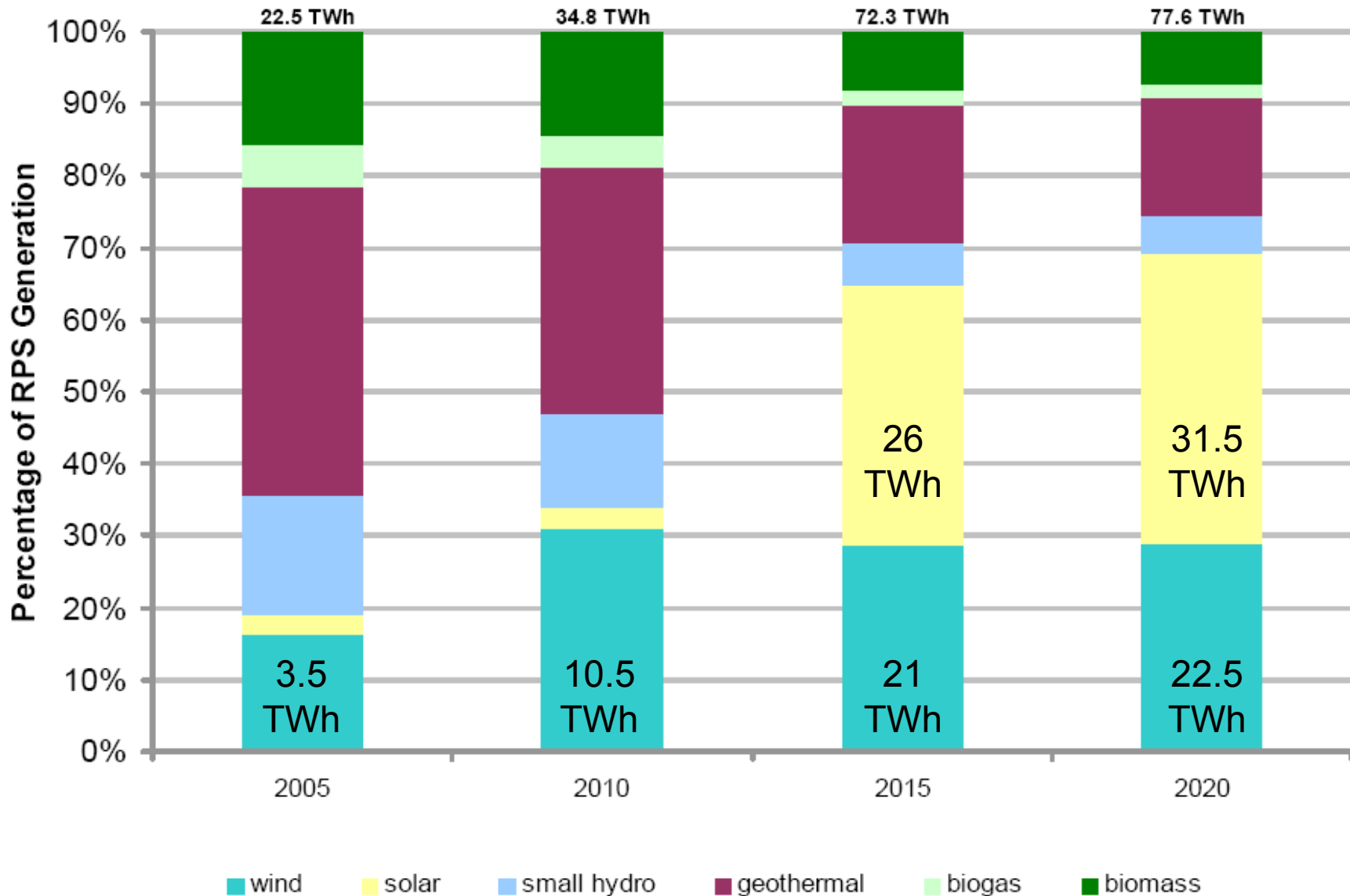




Renewable Resource Mix Projections



Source: California Public Utilities Commission, July 2009



Projected Wind and Solar Ramp Rates

4000MW SOLAR and 6000 MW WIND Nameplate Capacity

MW

5000

4500

4000

3500

3000

2500

2000

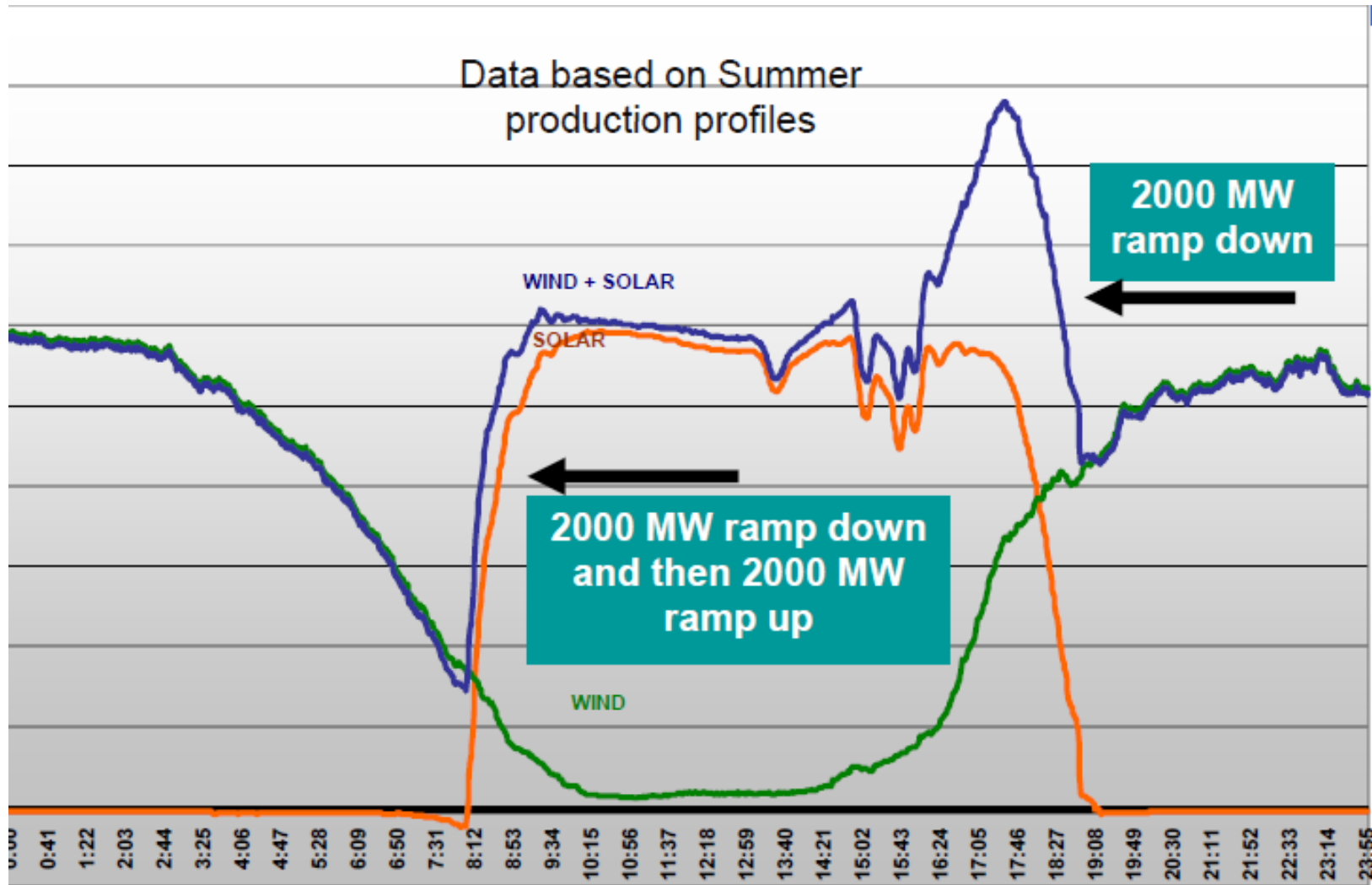
1500

1000

500

0

-500



Source: CAISO

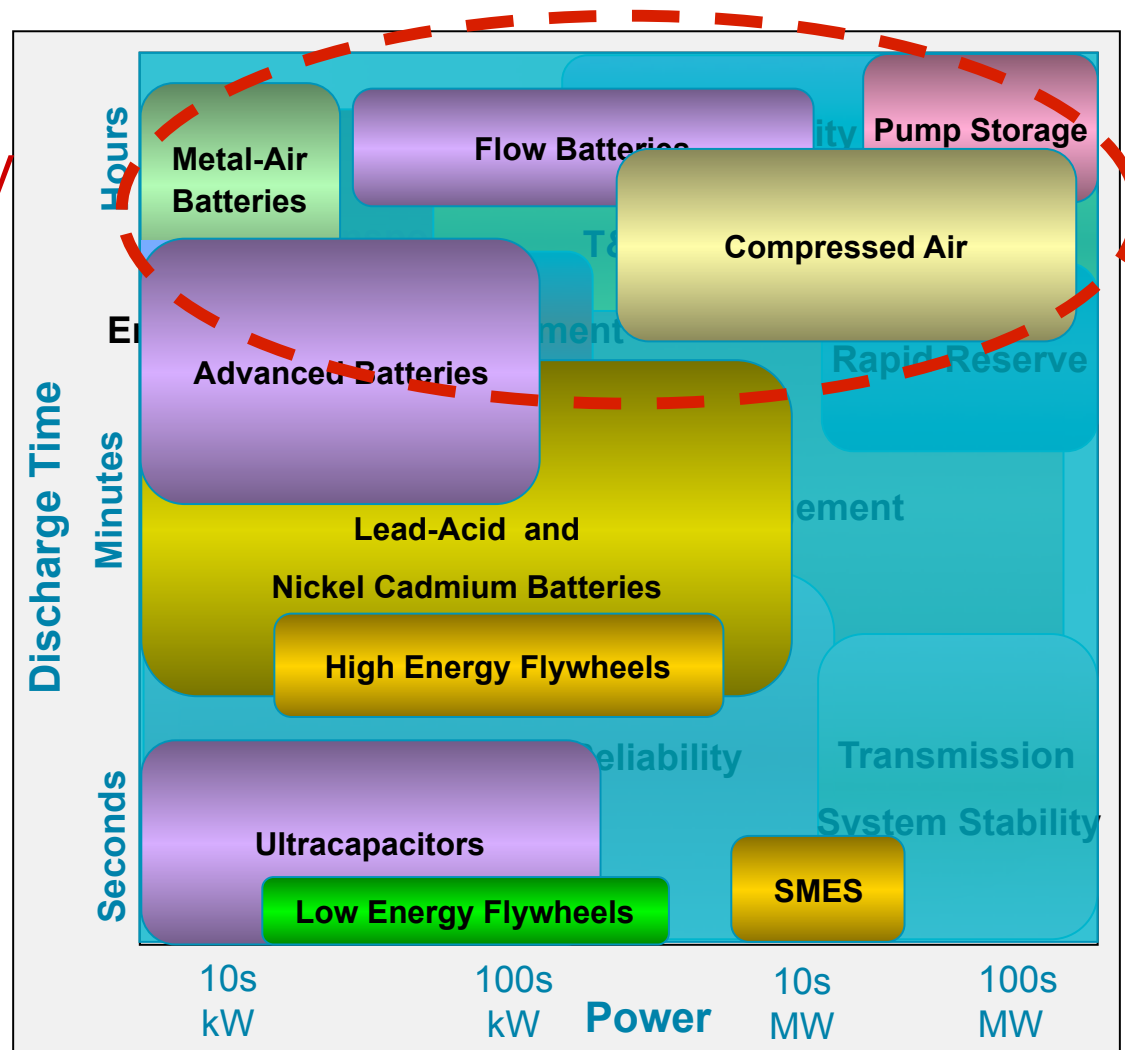


Energy Storage Technologies Analyzed

(Large Scale Energy Storage to Support CAIS Grid Operations)

The Only Commercially Available Large Scale Energy Storage Technologies Are:

- Pumped Hydro
- Compress Air
- Sodium Sulfur Battery Systems (If use 100's of battery modules)



(All Boundaries Of Regions Displayed Are Approximate)

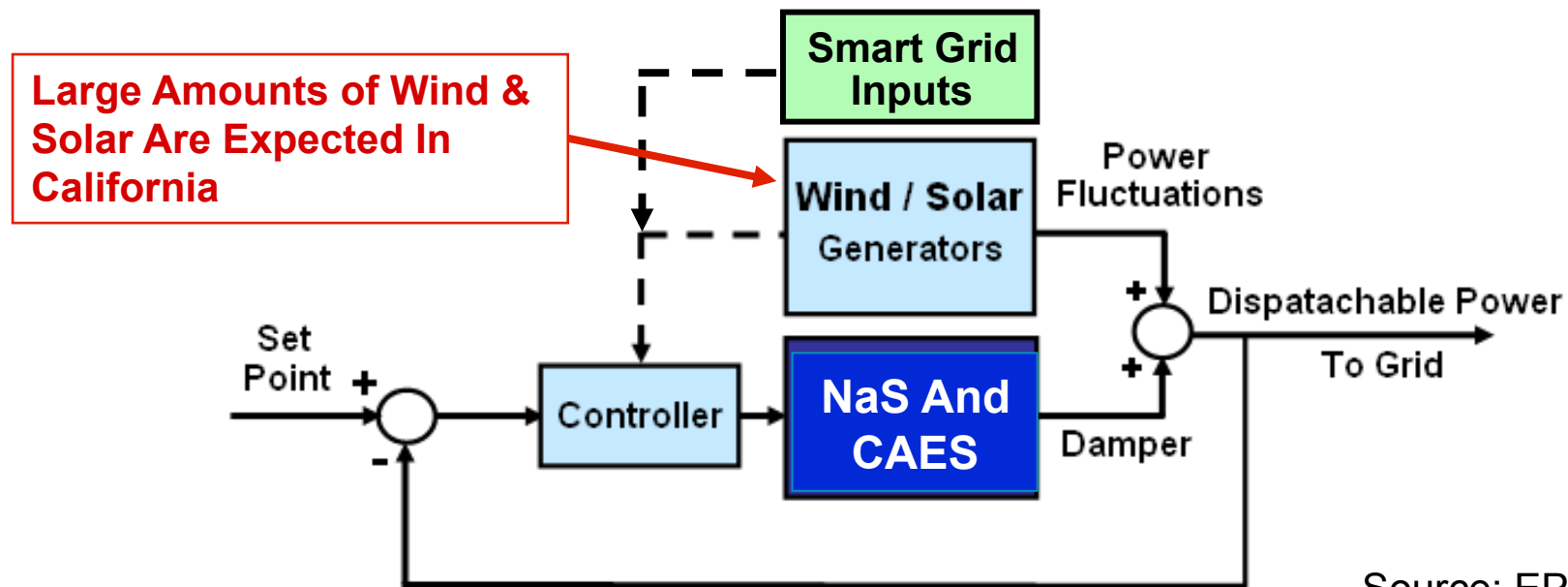
Source: EPRI



Problem: Wind / Renewable Plants Produce Power Output Oscillations Or Provide Power When Not Needed, Which Limits Their Value

Solution:

Deploy Electric Energy Storage Shock Absorber Plant, Which Is Sized and Controlled To Reduce Load Leveling, Ramping, Frequency Oscillation and/or VAR Problems



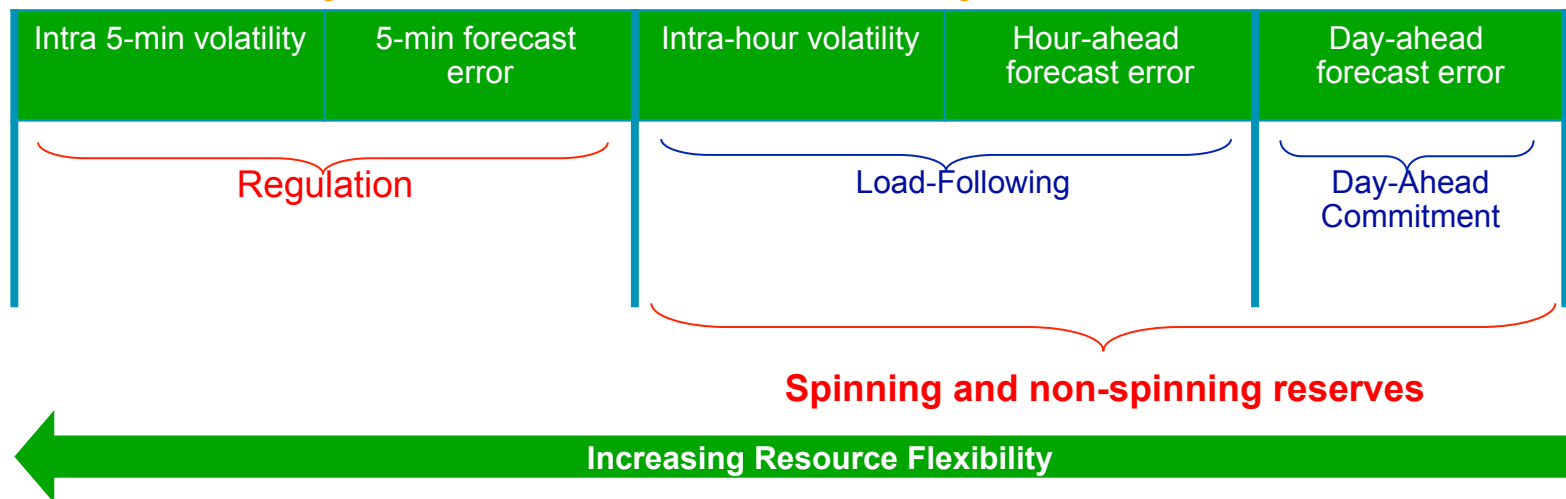


Resources Needed to Provide Ancillary Services

Ancillary services include:

- **Regulation Reserves (Reg Up/Down):** resources that can increase or decrease output instantly to continuously balance generating resources and demand
- **Spinning Reserves:** resources that are running (i.e., “spinning”) with capable of ramping within 10 minutes and running for at least two hours
- **Non-Spinning Reserves:** resources that are not running, but capable of being synchronized to the grid within 10 minutes, and running for at least two hours

Ancillary services address load volatility and forecast errors

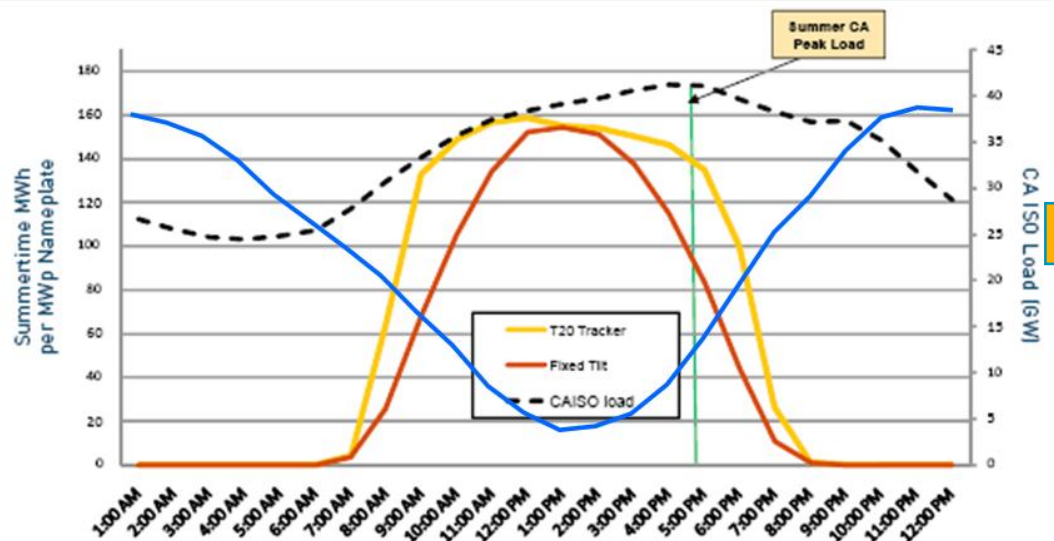




“Resource Adequacy” Required for Renewables Support

Renewable intermittency and mismatch with peak load contribute to the low RA values assigned to renewable generation

Peak Load Versus Renewable Generation Profile



Resource	RA Value
Nuclear	1.00
Natural Gas	1.00
Geothermal	.90
Concentrating Solar Thermal	.82
Solar PV	.57
Wind	.11

RA values are CAISO assigned and may not reflect actual contribution to meeting peak load.

Higher intermittent renewable penetration requires procurement of greater total generation capacity to meet forecast peak reliability need



PG&E NaS Battery Plant: Overall Project Description

- **4 MVA – 7 Hour Plant**
- **Partners**
 - **CEC – Co-Sponsor**
 - **EPRI – Monitoring and Performance Analysis**
 - **NGK – NaS Battery Manufacturer**
 - **S&C Electric - Turn-key Contractor**
 - **Hitachi – Customer Site**
- **Support from CEC, CPUC, and DOE**
- **Expected Operational Date: 2011**



PG&E NaS Battery Plant

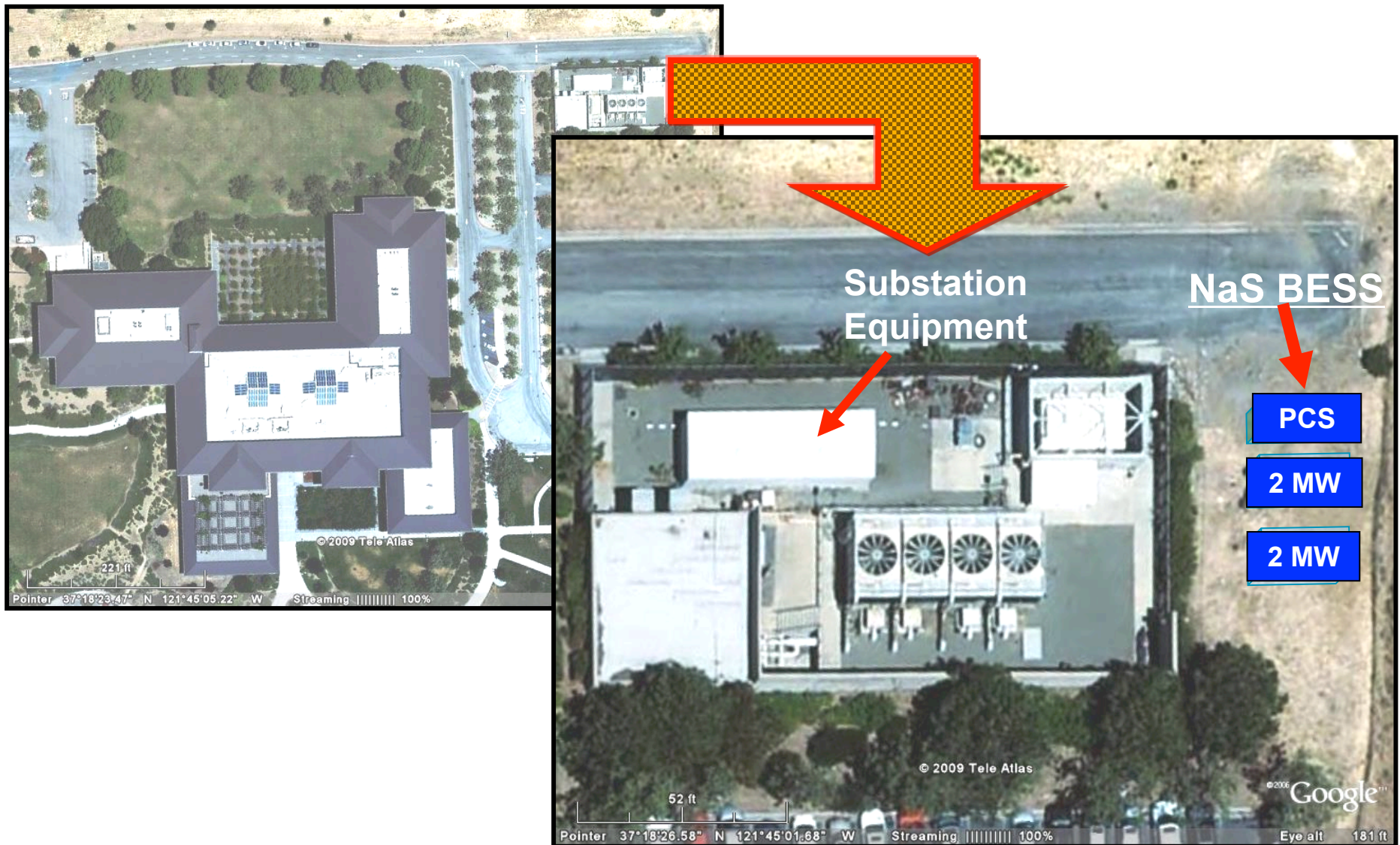
Project Objectives

- Reliability Improvement
- Load Shaping
- Renewables Integration
 - Grid Optimization
- System Operations
 - Ancillary Services
 - Demand Response
 - Black Start





Hitachi Plant Substation, San Jose, CA





PG&E Compressed Air Energy Storage (CAES) Plant: Overall Project Description

- **300 MW – 10 Hour Plant**
- **Partners**
 - **DOE, Co-Sponsor**
 - **CEC, Co-Sponsor**
 - **EPRI, Monitoring & Performance Analysis**
 - **Support from DOE, CEC, CPUC, Vendors**
- **Expected Operational Date: 2017**

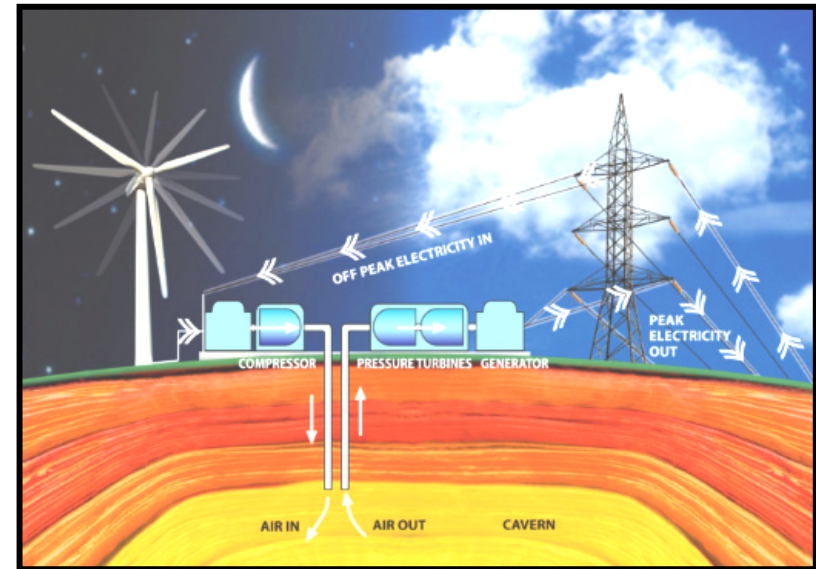


PG&E-DOE-EPRI Compressed Air Energy Storage (CAES) Project

300 MW, up to 10 hours storage*

3 phases:

1. Permitting, reservoir testing, transmission interconnection, plant design (\$25 million DOE match funding awarded 12/31/09)
2. Bid and plant construction
3. Monitoring



Partners:



Funded by:

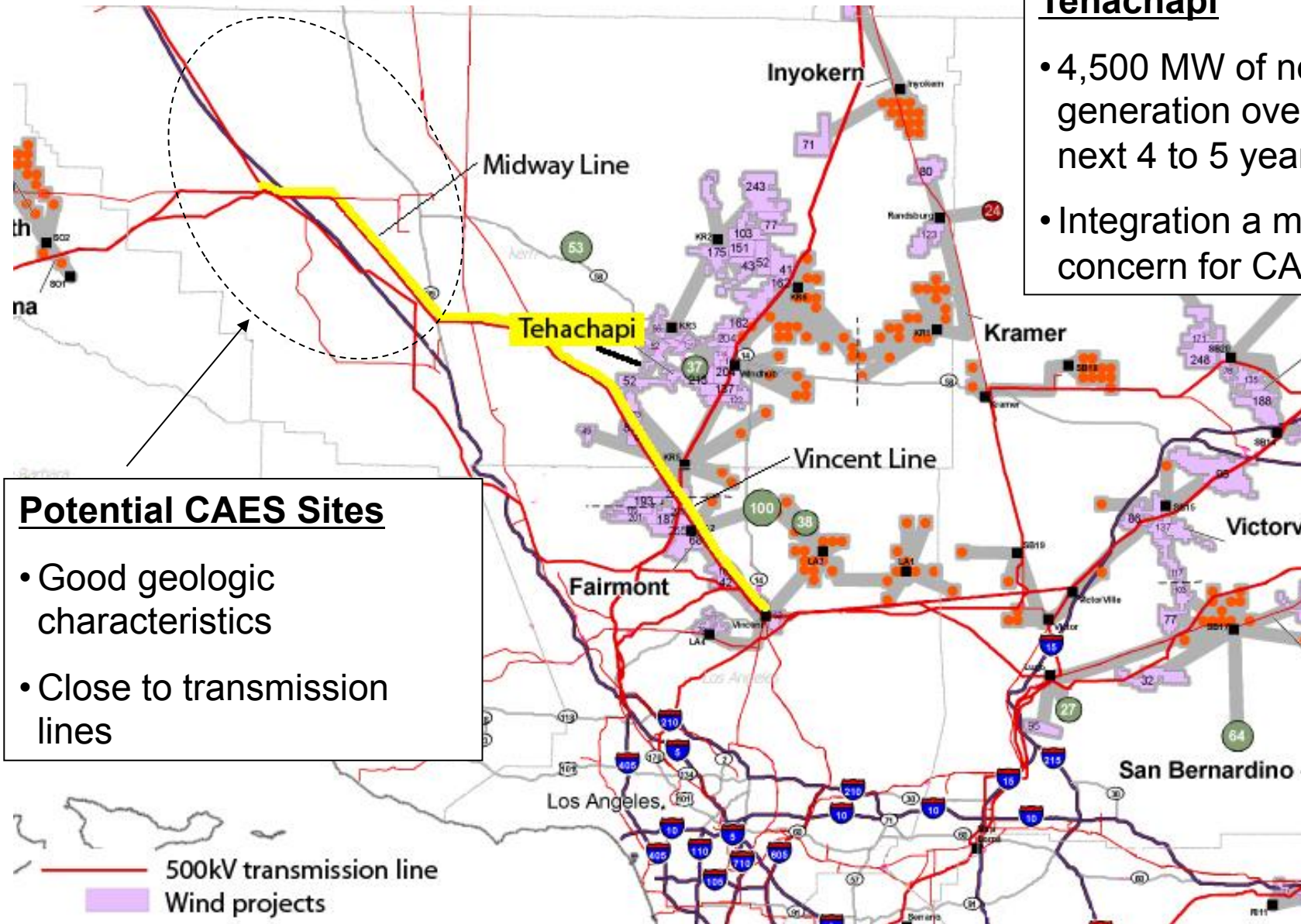


- Integrate intermittent renewables
- Store off-peak energy
- Provide ancillary services
- Manage peak demand
- Relieve grid congestion
- Use porous rock reservoir

* Final Project size will be determined by reservoir size and definition and by testing results, subject to management and CPUC approvals.



CAES Plant Site To Be Near Wind Resources



Tehachapi

- 4,500 MW of new wind generation over the next 4 to 5 years
- Integration a major concern for CAISO

Potential CAES Sites

- Good geologic characteristics
- Close to transmission lines



PG&E CAES Plant Has Attractive Operational Performance Characteristics



- Operates in both the charge and discharge modes simultaneously with a “flat” energy ratio & heat rate
 - This enables the plant to obtain spinning reserve and ramp up/down benefits while at part load.
- Plant is a flexible resource during the charge and discharge mode
 - In particular, at part load operation the plant provides a combination of arbitrage, frequency regulation and ramping benefits
- Ramp rate is about +/- 40% minute
 - For example, a 300 MW Advanced CAES Plant that is synchronized to the grid, can change output power at +/- 120 MW's per minute. This makes the plant effective at performing up-ramps and down-ramps as wind power fluctuates, and/or, as market price signals change.



Summary

- **PG&E NaS Battery Plant (4 MW – 7 Hours):**
 - **Commercially Available With Warrantees**
 - **Response Time: Seconds**
 - **Excellent Application To Mitigate Power Fluctuations From Solar Plants, Provide Frequency Regulation And To Control Real & Reactive Power To Key Industrial Customers**
 - **Planned Operational Date: 2011**
- **PG&E CAES Plant (300 MW – 10 Hrs.)**
 - **Lowest Cost Large Scale Energy Storage Plant**
 - **Response Time: Minutes**
 - **Excellent Application To Control Large Power Fluctuations From The Increasing Amount Of Wind and Solar Plants**
 - **Planned Operational Date: 2017**



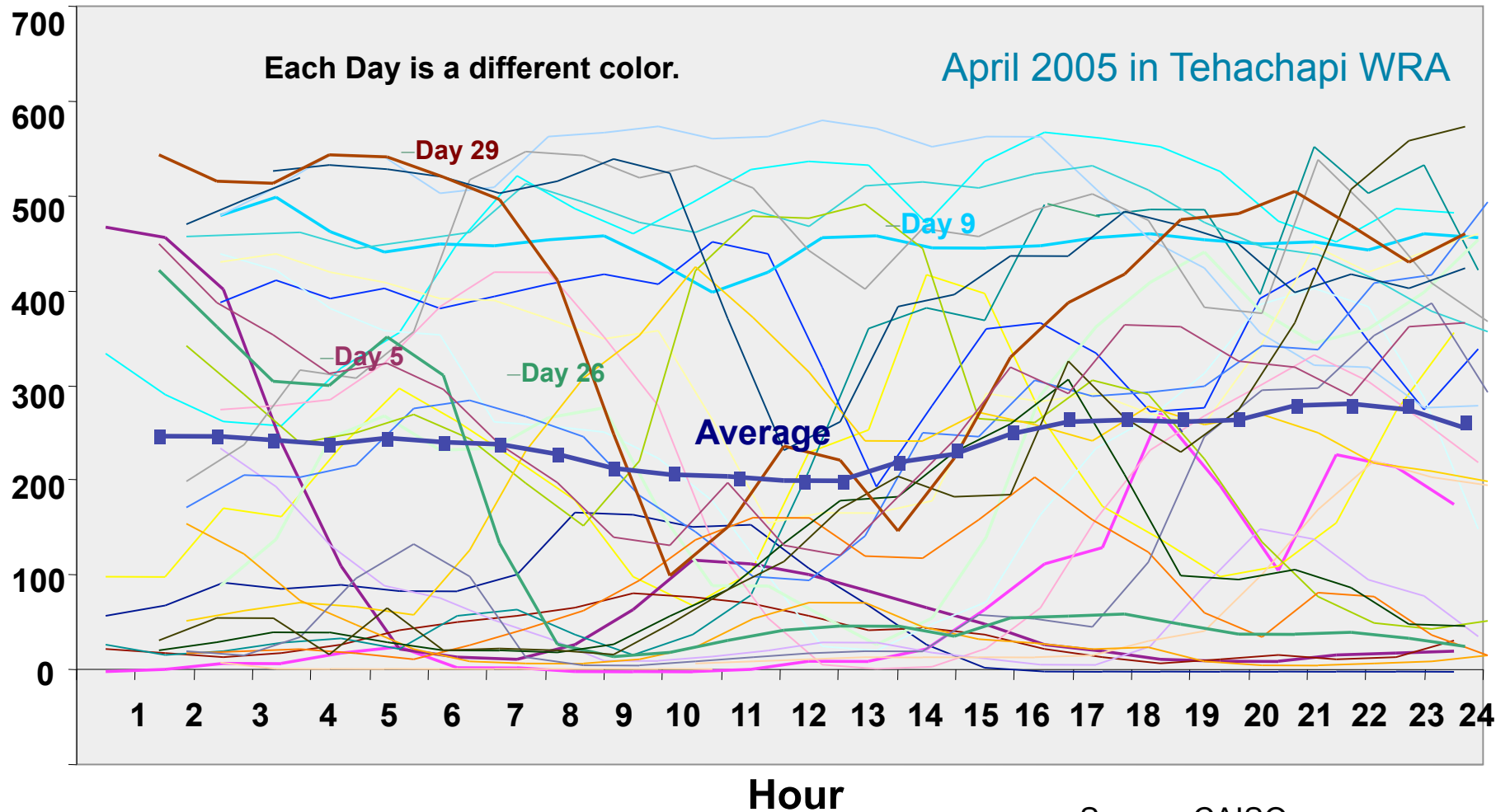
Questions ?



Wind Generation Varies Widely

MW

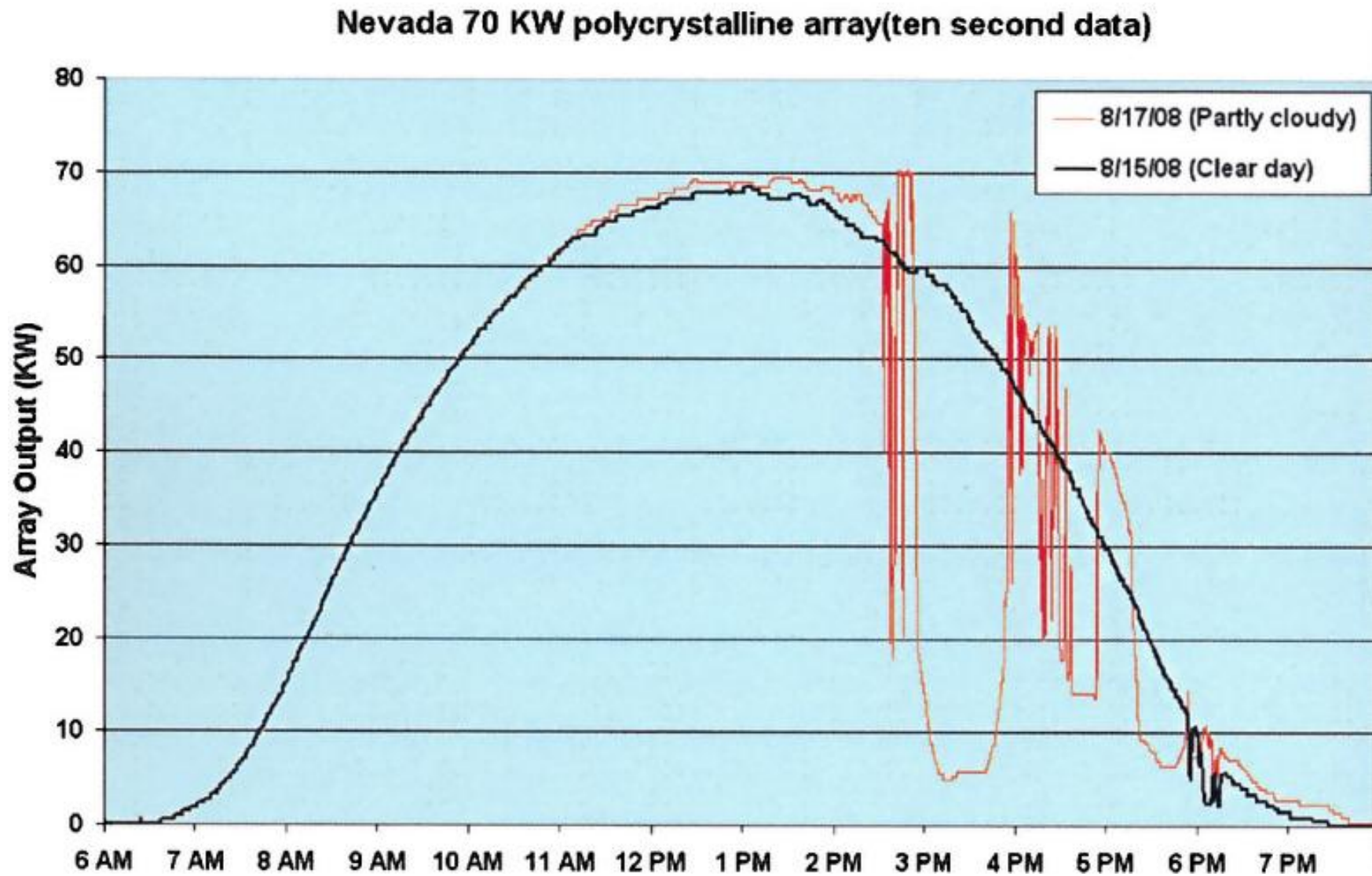
The average is smooth, but day-to-day variability is great



Source: CAISO



Large Variation of Solar PV System Output



Source: AES

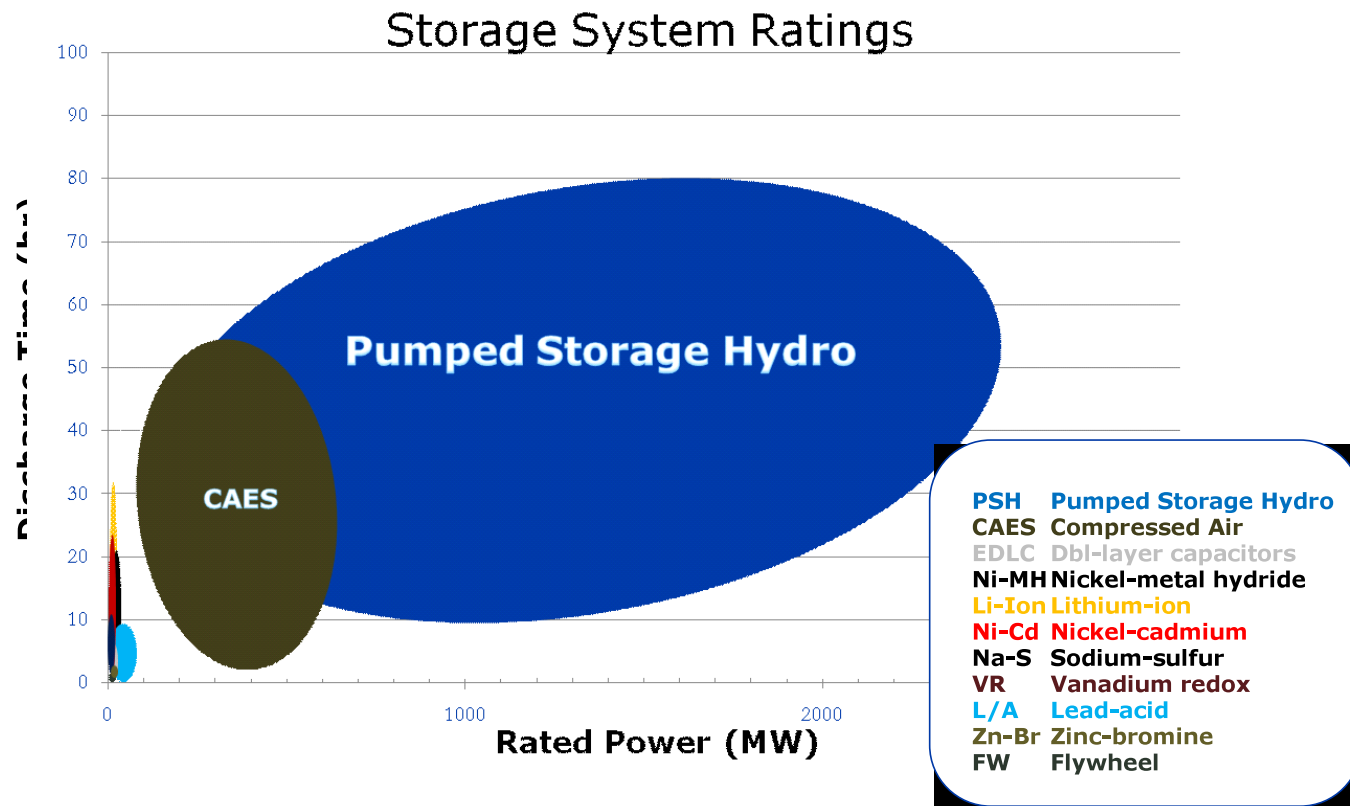


Why CAES?

- It Meets Utility-Scale Needs

Appendix

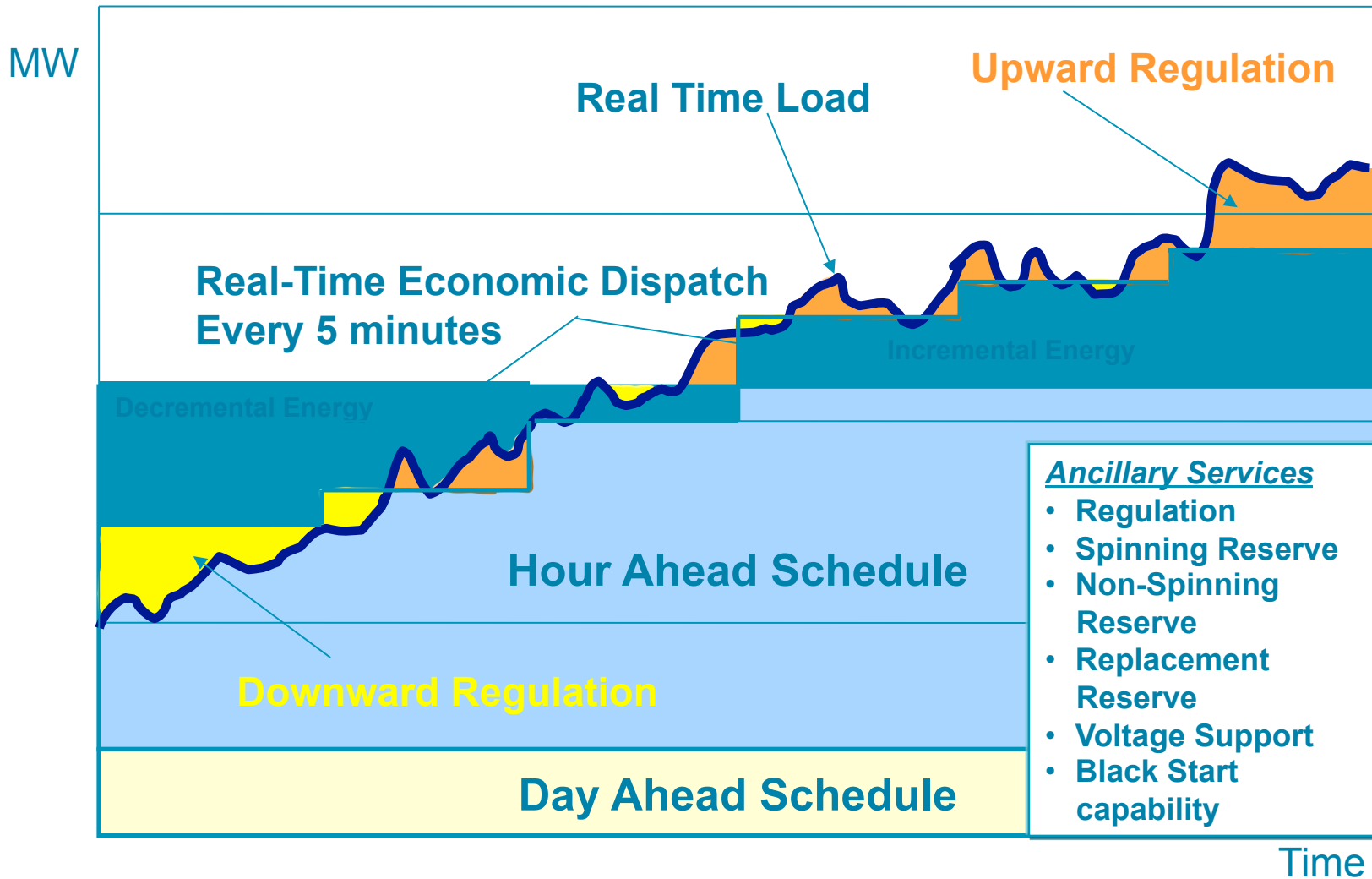
Energy Storage Technologies



Source: Same as prior graph by Electricity Storage Association (converted to normal scale by Rick Miller, HDR | DTA)



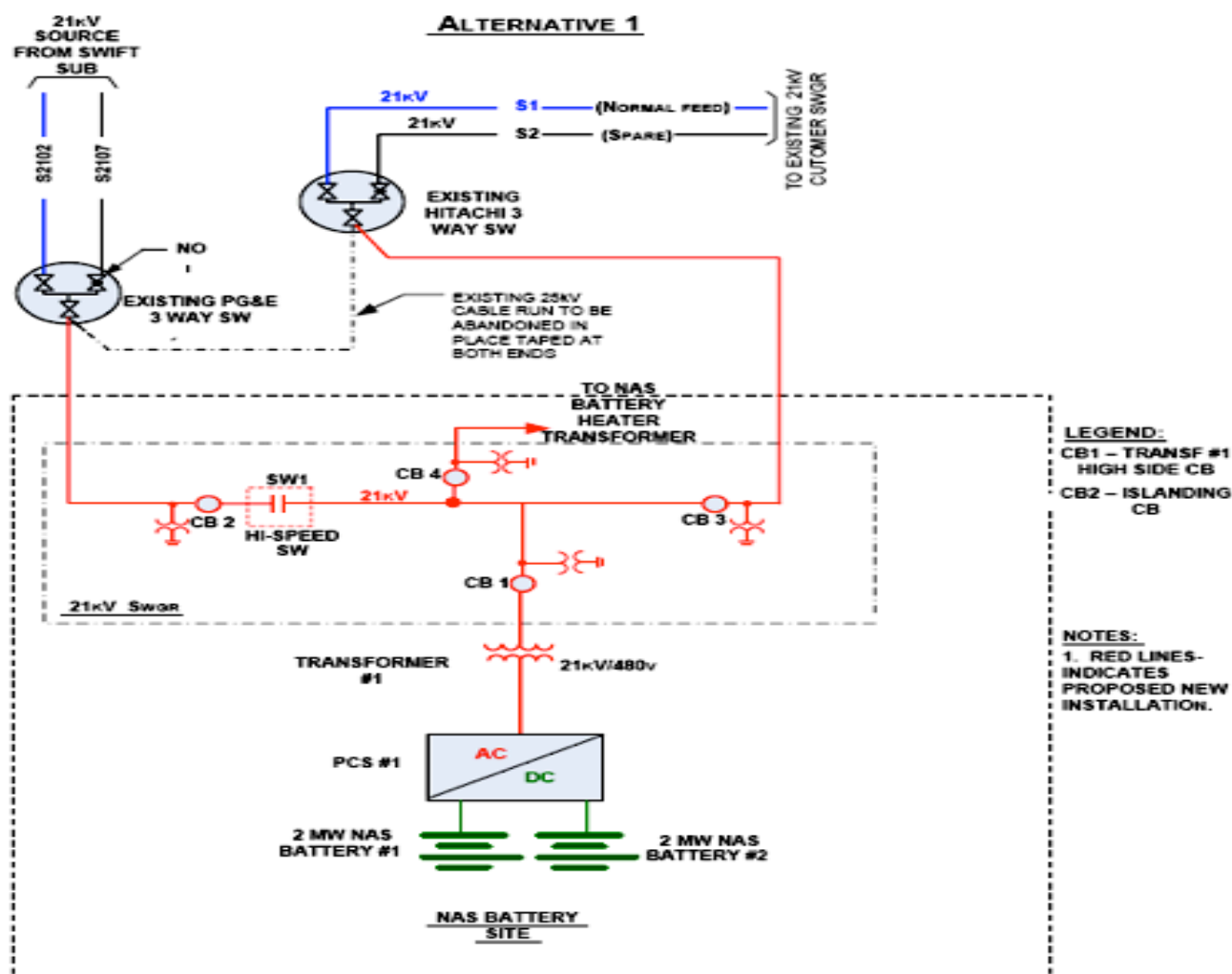
Balancing Function - Area Control





PG&E NaS Battery Plant: Single Line Diagram (Draft)

Appendix



Hitachi Substation Schematic